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PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the application of:

WATSON et al.

Serial No.: 09/926,004 Group Art Unit: 1755

Filed: November 14, 2001

For: OBSTRUCTION DETECTION SYSTEM

CLAIM TO PRIORITY

Assistant Commissioner of Patents
Washington, D.C. 20231

Sir:

The benefit of the filing date of the prior foreign application filed in the following foreign country is hereby requested and the right of priority provided in 35 U.S.C. §119 is hereby claimed:

New Zealand Application No. 334144 filed 11 February 1999.

In support of this claim, filed herewith is a certified copy of said foreign application.

Respectfully submitted,

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Date: January 30, 2003
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Intellectual Property Office of New Zealand
Te Pou Rāhui Hanga Hou

CERTIFICATE

This certificate is issued in support of an application for Patent registration in a country outside New Zealand pursuant to the Patents Act 1953 and the Regulations thereunder.

I hereby certify that annexed is a true copy of the Provisional Specification as filed on 11 February 1999 with an application for Letters Patent number 334144 made by T L JONES LIMITED.

Dated 9 January 2003.

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Neville Harris

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Commissioner of Patents

334144

OBSTRUCTION DETECTION SYSTEM

Field of the Invention

The present invention relates to obstruction detection systems. More particularly, but not exclusively, the present invention relates to methods and apparatus for detecting obstructions between or in the vicinity of elevator doors. The present invention may also be applied to obstruction detection in the context of industrial environments, safety applications, monitoring machinery activity, process control and the movement of people.

Background Art

The following discussion will be primarily directed towards obstruction detection methods and apparatus for use in elevator door systems. However, it is to be understood that this is not intended to be a limiting application. In certain circumstances and with appropriate modification, the invention may be suitable for use in other obstruction detection situations discussed elsewhere in this specification.

To the present time, there are a large number of techniques and devices which may be used for detecting obstructions within either static volumes or variable locations. For a general discussion of such techniques, see applicant's International Application PCT/NZ95/00067.

Generally such prior art techniques focus on using optical devices to detect the presence of an obstruction or obstructions within a lift door detection area. These known systems typically use arrays of infra-red (IR) emitters with corresponding receivers. One prior art technique consists of "shining" a sequential array of IR beams across an elevator door entrance an obstruction event is triggered by interrupting or breaking one or more of the beams. Such an event activates a relay which reverses or stops movement of the elevator door. An advantage of

such systems is that they can be located along the edges of the moving doors and can thus be specifically adapted to deal with variable geometry entrance obstruction detection in the plane defined by one or more elevator doors.

Such techniques are generally satisfactory for detecting obstructions in the area directly between elevator doors. However, limiting obstruction detection to the door plane is now considered insufficient to meet contemporary industry safety standards. There is impetus in the lift industry to develop a lift door obstruction sensor that is not only capable of detecting obstructions in the area between the elevator doors, but also has detection capability that extends past the doors out to the end of the architrave situated on the landing. Accordingly, there is a need to either be able to upgrade existing two-dimensional door obstruction sensing arrays to incorporate three-dimensional functionality or to provide a new integrated door plane and vicinity obstruction detection system.

Previous attempts to address the abovementioned industry trend include those described in US patent no. 5,387,768 (*Otis Elevator Company*). This patent describes a technique whereby an obstruction event is triggered by people approaching a lift as opposed to standing stationary in front of the lift. That is –this specification describes what is essentially a movement detector. The system uses masking techniques to remove regions of the lift/area image that are not relevant to obstruction detection. The system detects passengers, controls the movement of the doors and counts the number of passengers in an attempt to minimise waiting time between elevators.

To implement this functionality, the *Otis* imaging system collects images at two different times and then uses the difference between the two images to determine whether there is a moving object in the elevator obstruction detection zone. This technique relies on the use of

a reference image which is captured at a time before the second obstruction detection image is recorded. The two images are then subtracted and thresholded to produce an image containing only the outlines of the objects that have moved during the interval between collecting the first and second image.

The system includes separate masks for the hall area and elevator sill. The hall mask masks out variable portions of the image where the masked image size depends on whether any motion has been detected in that particular region or the viewing area. That is – if a person is standing at the back of the hall and not moving, that region of the image is masked out by virtue of the lack of movement detection. The sill mask increases in size as the doors close thereby removing the doors from the image that is to be processed.

Thus, the most relevant prior art describes techniques that detect objects and masks out regions of non-interest based on response to movement.

A number of other prior art techniques (see for example US patents Nos. 5,284,225 and 5,182,776) disclose systems which again use reference images that are compared with later collected "active images". Such techniques conventionally use image subtraction whereby the reference images are subtracted from those collected at a later time to determine whether any obstructions have entered the obstruction detection zone. These techniques exhibit a number of disadvantages in that time-based obstruction detection systems may not be sensitive to time intervals longer that a certain a threshold. This may produce problems where there is rapid transitory movement in an object following a stationary period. Also, known techniques can be difficult to implement given the large degree of possible variation between elevator door environments. For example, variations in furniture (and other permanent fixtures), floor covering patterns and the like can hamper the detection of incremental changes in a visual scene

based on time differences. This is particularly so if the reference image must be set at an early or fixed stage.

It is therefore an object of the present invention to provide a method and apparatus for detecting obstructions which embodies reduced reliance on temporal variations between active images and reference images, is fast and generally insensitive to large variations in the character or visual appearance of the obstruction detection area environment or at least provides the public with a useful choice.

Disclosure of the Invention

In one aspect the invention provides for a method of detecting obstructions and/or movement in obstructions, the method including the step of detecting parallax in two or more images of an obstruction detection area, the parallax produced either by the presence of an obstruction in the obstruction detection area.

The method may include the step of detecting temporal changes in the images of the obstruction detection area.

The method may include the step of detecting vertical and horizontal parallax produced by an obstruction located in an obstruction detection area.

More particularly, the invention provides for a method of detecting obstructions including the steps of aligning backgrounds of a plurality of images of an obstruction detection area and subtracting pairs of images so as to reveal, by way of parallax, the presence of obstructions in the obstruction detection area.

Even more particularly, the invention provides for a method of detecting obstructions including the steps of aligning backgrounds of a first and second image of an obstruction detection area and subtracting the first image from the second, thereby revealing, by way of parallax, the presence of a three dimensional object.

In a preferred embodiment, the method comprises the steps of:

(a) Collecting a first image of an obstruction detection area from a first viewing point;

(b) Collecting a second image of an obstruction detection area from a second viewing point;

(c) Calculating the shift between the backgrounds of the two images;

(d) Aligning the background of the two images;

(e) Subtracting the two images to produce a third difference image;

(f) Analysing the third difference image to detect parallax thereby revealing the presence of a 3-dimensional object in the obstruction detection area.

Preferably subtraction step (e) is followed by a thresholding step whereby the difference image is thresholded to exclude noise thus producing a binary image.

Preferably the third difference images is manipulated so as to contain substantially only the outlines of any 3-dimensional objects in the obstruction detection area.

In an alternative embodiment, the images are divided into background images and door edge images wherein calculation of the necessary shift between the backgrounds of the two images is based on the images of the background when no obstruction is present.

Preferably the shift is calculated using cross-correlation.

Preferably, the images are blurred with gaussian, median or similar filters so as to reduce the effect of pixelation in the images.

The invention also provides for an apparatus for detecting obstructions in an obstruction detection area, said apparatus including:

at least one imaging means adapted to image substantially the same scene from at least two spatially separate viewing points; and

microprocessor apparatus adapted to manipulate said images in order to calculate the shift between the backgrounds of the two images or pairs of images, align the background images based on said shift, subtract the resulting images to produce a difference image thereby allowing the detection of parallax effects in the difference image thus signifying the presence of a potential obstruction event.

The images may be manipulated optically, mathematically or in a like manner which reveals parallax in the image of the obstruction detection area.

Preferably the microprocessor is further adapted to threshold the difference image.

The microprocessor may be in the form of a solid state, optical or the like device.

In cases where a single camera is used, the apparatus further comprises an optical arm and reflection means adapted to relay an image from a viewing point that is displaced from the physical location of the camera.

The collection of parallax images may be effected by optical means including prisms, light guides and the like or alternatively the imaging means themselves may be translated or suitably displaced.

In a further aspect the present invention provides for a method of detecting obstructions in relation to the plane defined by an elevator door, said method including using horizontal and/or vertical edge detection in such a way so as to highlight the substantially dominant vertical and horizontal lines in an image.

The horizontal and/or vertical edge detection may be effected by means of filters, differentiators and the like.

Preferably the method comprises two steps, the first step consisting of detecting the location and dimensions of a door sill and the second step consisting of detecting the location and dimensions of one or more door edge(s).

Preferably the first step comprises using substantially horizontal and/or substantially vertical edge detection filters to highlight the dominant vertical and/or horizontal lines in the part of the image where the sill is known to be approximately located;

summing the intensity values along each row of pixels in the image(s) producing using the vertical and/or horizontal edge detection filters thus producing a vertical and/or horizontal function with global maxima and/or minima corresponding to the position of the horizontal runners and/or vertical edges of a sill thereby providing information relating to the spatial position of the sill in terms of horizontal and vertical features in the image.

Preferably, the second step comprises:

using the previously determined position of the sill and knowledge of the physical relationship between the sill and the door edge(s) to obtain a coarse estimate image of the door edge position;

subjecting the coarse estimate image to edge detection filters adapted to highlight edges oriented at a known angle;

adding the resulting images to produce a summed image and optionally thresholding the summed image to produce a binary image, the binary image consisting of one of more linear features corresponding to the door edges; and

deriving equations for the linear features in the image.

Preferably the known angle is 45° and 135°.

Preferably the summed and thresholded image is multiplied by a ramp function which increases in magnitude in the vertical direction.

Preferably the equations of the linear features are obtained by locating the line(s) by means of a least squares technique whereby, once the equation for each line has been determined, the line is deleted and the next line considered in turn.

Brief Description of the Drawings

The invention will now be described by way of example only and with reference to the figures in which:

Figure 1: illustrates a flow chart showing the steps in a parallax-based method for detecting obstructions in an obstruction sensing area;

Figure 2 illustrates data produced according to the method of Figure 1 as applied to a sample obstruction (a ladder) in an elevator door;

Figure 3 illustrates the detection of machine recognisable parallax for a number of sample obstructions;

Figure 4 illustrates the ability of filtering techniques to reduce artefacts produced by the pixelated nature of the detected images;

Figure 5 illustrates an edge detection technique as applied to determining the horizontal and vertical position, in an image, of an elevator door sill;

Figure 6 illustrates the separation of a door region image into two coarse door edge regions;

Figure 7 illustrates schematically the steps in an algorithm used for locating positions of the door edges;

Figure 8 illustrates data produced according to the method of figure 7;

Figure 9 illustrates the parameterisation step in the method of figure 7;

Figure 10a-f illustrates sample data for a door edge obstruction event.

Figure 11 illustrates schematic views of parallax imaging systems;

Figure 12 illustrates the division of the imaged scene into detection and masked zones;

Figure 13 illustrates an arrangement of parallax detection system in a lift door; and

Figure 14 illustrates schematically the connection of two imaging devices.

The following description will be given in the context of obstruction detection in elevator door systems. This is to be understood as not to be a limiting feature of the invention. The apparatus and method of the present invention may be applied to obstruction detection applications, for example the monitoring of industrial machinery, security applications in the like.

Referring to figure 1, the steps in a preferred embodiment of the invention are shown. A key novel feature of the invention resides in the application of the parallax effect to obstruction detection. To this end, two images 1 and 2 are collected from spatially separate vantage points. These images correspond to the scene looking down into an elevator doorway from two different locations (see Figure 2a and 2b). The views encompass the immediate vicinity of the elevator doorway – this being the area where normally users of the lift would approach the lift doors. This vicinity can be broken down into a door edge protection zone – defined by the plane between the doors and the wider protection zone through which users pass when approaching the lift.

In one embodiment, the images are recorded by spatially and physically distinct imaging systems. These may include known optical imaging systems such as charged coupled device (CCD) cameras. In an alternative embodiment (not shown), a single camera may be used whereby one or more optical arms directs an image of a first view (viewed from a first vantage point) and second view (from a second vantage point) to the single camera. The first and second images are compared to determine whether any parallax effects are detected in the obstruction detection area. This imaging could be controlled by an optical cell which would alternately interpose a reflector or other type of interception device into the field of view of the camera thus diverting the view to the spatially displaced vantage point. Alternatively, optical waveguides could be used to transmit separate views to a single camera.

Referring to Figure 2, this principal is illustrated by means of placing a ladder immediately outside the door edge detection zone of a lift door (i.e. in the wider detection zone). Two images, 2a and 2b are recorded from different vantage points. The shift between the backgrounds of the two images is calculated and used to align the background of one scene with the other. The amount of alignment of the backgrounds would preferably be minimised by ensuring that the optics of the system are as precisely aligned as possible during their manufacture. Any minor imperfections in the alignment of the backgrounds could then be compensated for by a suitable mathematical image processing technique. In the preferred embodiment the preferred technique for correcting for such imperfections is by way of cross-correlation or minimum energy. The minimum energy technique involves 'shifting' the image (in two dimensions) by a pixel at a time (in an ordered manner in each direction). The resulting two images are subtracted and then all of the pixel values summed in the difference image. The required shift to align the images most accurately is then that which results in the minimum

summation value. That is – when the difference image sum is minimised, alignment is optimised.

Cross-correlation is a statistical technique which is generally more robust and faster than techniques based on minimum energy. Further, significant enhancements in processing speed have been found when cross-correlation is effected via fast Fourier transforms.

Complete cancellation of the background has been found to be impractical due to inaccuracies in determining the shift due to parallax, incomplete cancellation due to noise, the effects of pixelated images, non-linear distortion, rotation in the image plane of the cameras and the differences in lighting observed from the two different vantage points.

The error introduced by image alignment effects would depend on both the size of the 3-dimensional object relative to the background and the magnitude of the parallax that the object produces. To minimise this error, a section of the images containing no or minimal parallax and maximum background, can be used to calculate the shift necessary to align the backgrounds of the images.

The mathematical techniques that are used to compute the shift between the backgrounds of the images assume that the images are infinite. Real images are finite and as a result, these techniques tend to underestimate the shift. These effects can usually be overcome by forcing the image to zero at its perimeter before using a mathematical technique to compute the shift. This is achieved by multiplying the image by a function (such as a two dimensional cosine function) that is zero valued at its boundary (perimeter). When this is done, it has been found that the shifts tend to be correctly calculated and the difference images have only a relatively small contribution from background that is not completely cancelled.

Additional sources of error come from noise. However, the overall effect of this is generally minimal.

A further source of error in background shifting is pixelation of the elements of the picture. Real images are, by their nature, discrete at their boundaries and as they are viewed from two different vantage points, it is not possible to align the backgrounds of the images exactly or cancel the backgrounds completely. This is due to the fact that the edges of objects within in image will not always lie precisely on a pixel boundary. The edge of an object will generally overlap the pixel boundary and therefore shifts will not always correspond to an integer number of pixels.

This error can be largely overcome by blurring or smearing the image so that each pixel has an intensity value that is an average of its surrounding pixel values. In prototyping, it has been found that gaussian and median filtering is particularly effective in this regard.

Errors due to image rotation can be largely reduced by accurately aligning the optics during manufacture. Illumination errors can be minimised by using a system that implements a single camera and hence the same exposure and aperture control system, in order to obtain two images which are unaffected by differences in lighting intensity. Parallax effects can then be obtained using a single camera in conjunction with a mirror/lens system to obtain spatially separate views whereby the resulting images are focused onto separate halves of the charge couple device within a single camera. It is not necessary that the image be split onto separate halves of the imaging device. A switching means may be used to select the required image which is then focussed on the CCD device.

Once the shift between the backgrounds of the two initially collected images is calculated, the backgrounds are aligned and then subtracted in order to produce a difference image. This is shown in Figure 2c. As can be seen, the background and lift sill contribution to the image is substantially cancelled while the obstruction (in the present case a ladder) is emphasised. To enhance the parallax effect, the resulting image is preferably thresholded thus producing the significantly more intense representation of the parallax as shown in Figure 2d.

Ideally, the difference image will contain only outlines of the three dimensional objects. However, in practise, the resulting parallax-highlighted image is as shown in Figure 2d.

The present technique has been found to be particularly useful in detecting people proximate to or entering an elevator. This is because as the height of an object increases, the parallax effect becomes more noticeable thereby allowing more accurate and clear identification of the obstruction.

Figure 3 illustrates the result of placing a variety of sample obstructions immediately outside an elevator door. Figures a, d, g, j and m illustrate a box; box on a rug; a cane; a soft toy (representing an animal); and the leg of an approaching user. The corresponding difference image (figures 3b,e,h,k and n) are shown along with subsequently thresholded difference images (figure 3c,f,i,l and o). As can be seen, the existence of a patterned rug can hamper effective subtraction of a background. However, even with significant background, the thresholding step significantly enhances the machine detectable position of the obstruction.

Thus a machine recognisable parallax effect is produced when an obstruction is moved within or placed in the obstruction detection area. As Figure 3a illustrates, parallax is primarily produced by the parts of the image corresponding to the vertical edges of the box and not by the

horizontal edges. This is due to the fact that the cameras are displaced horizontally at the top of the lift doorway and therefore horizontal parallax effects will be minimised. The parallax produced by the right hand door edge is also clearly visible and it can be seen that the size of the parallax decreases and eventually vanishes as the door edge approaches the sill or floor area.

Figure 4 illustrates the ability of filtering techniques (discussed in detail above) to reduce pixelation artefacts for identical sample images to those shown in figure 3. Figures 4c, f and i (when compared with figures 3f, i and o) illustrate that filtering reduces the level of the background cancellation remnants without suppressing the features produced by parallax. The effectiveness of this technique is evident as it can be seen that the previously visible horizontal lines due to the runners on the door sill are now absent. This is desirable given that these features belong to the background and are not attributable to the parallax effect caused by an obstruction.

A further aspect of the present invention resides in the identification of linear features for use in obstruction detection where elevator door edges (for example) are obstructed.

In such an application, it is desirable to separate the images of these areas into images of the door edge detection zone and the wider detection zone. These zones are generally illustrated in Figure 12 which also shows the position of the lift sill and door edges. These zones are subject to different obstruction criteria with associated degrees of importance. The door edge detection zone corresponds to the area or the plane defined by the door sill and the edges. The detection of obstructions in these zones must be 100% reliable, as any obstruction will almost certainly be hit by a moving elevator door.

Another reason for treating the images separately is that the door edge produces a substantial parallax effect. This can potentially swamp the parallax produced by smaller three-dimensional objects located in the wider obstruction detection zone. Therefore, by separating the images into these defined areas, the algorithm used to detect parallax will be capable of detecting parallax primarily in the wider obstruction detection zone.

The door edge detection technique according to the present invention is divided into two steps. The first step examines the image in order to detect the door sill. The second step identifies the edges of the door. Figure 12 shows the relative positions of these components.

Identifying linear features corresponding to the sill in the image involves using horizontal and vertical edge detection filters to highlight the strong vertical and horizontal lines in the lower half of the image (this being where the sill is assumed to be located in the image). The horizontal runners can be seen in the lower part of Figure 5b. It can also be seen in Figure 5d that the horizontal edge detection emphasises the horizontal lines due to the sill and the door runners.

Following this, the intensity values along each row of pixels in an image are summed. For example, see Figure 5f. As can be seen, the result is a function which has peaks located at the positions of the runners and edges of the sill (when scanned in the vertical direction). These peaks can be quite easily detected in order to provide the location of the sill.

To determine the width of the sill (the horizontal part of the elevator door zone), the image shown in Figure 5b is subjected to a vertical edge detection filter. The resulting image is that shown in Figure 5c which emphasises the vertical lines that occur where the sill meets the door edges. In a similar fashion as for the runners, the intensities in each column of pixels of

Figure 5c are summed to produce the function shown in Figure 5e. The peaks in Figure 5e correspond to the horizontal position of the sill edges.

The above technique provides both the horizontal and vertical locations of the sill and it is thus possible to separate out the sill from the image. As the edges of the sill are attached to the lower part of the door edges, it is also possible to separate out a coarse estimate of the left hand and right hand door edges. This is shown in Figure 6 where images of the left and right-hand door edges are visible. These coarse estimates are then used in the second step of the method for identifying the door edges.

To obtain the location of the door edges, the coarse estimates (see Figure 6) are processed according to the technique illustrated in Figure 7. Initially, the coarse estimate images are subjected to edge detection filters which are adapted to highlight edges oriented at 45° and 135°. This is illustrated in Figure 8b (for the left-hand edge). The resulting images are then added and preferably thresholded in order to create a high-contrast binary image (see figure 8c). The image thus consists of a number of lines that correspond to linear features in the door edge image. Equations describing the position of these lines are then derived. This is done by started at the top of the image and locating one line in the image at a time and parametrising it preferably using a least squares technique. Other mathematical optimisation techniques may also be suitable. This line is then erased and the next line processed in turn (for this sequence, see figure 9 top to bottom). To ensure that lines at the very top of the image are being analysed, the binary image (figure 8c) is multiplied by a ramp function that increases in intensity towards the top of the image. The result of multiplication by such a ramp is shown in Figure 8d.

The detection of edges in the context of elevator doors is particularly critical. Over time, people have developed the habit of placing their hand in the door gap in order to stop the

elevator doors closing. It is therefore important that any obstruction detection system can detect hands or other objects being put between the closing doors.

It has been found that the parallax obstruction detection technique described earlier in this specification can also be used to detect a hand or other obstruction on the door edge. In trials, the parallax produced by a hand on the edge of the door was clearly machine detectable. Clearly if this technique was to be implemented in a practical form, it would be necessary to be able to distinguish the parallax produced by the door edge itself from that produced by the presence of a hand or other obstruction. The previously described technique for identifying the door edges in an image could be used for this purpose.

An additional technique that could be used to identify such obstructions is to obtain reference images of the elevator door edges in a situation where no obstructions exist. Such reference images could continually be compared with the images of the car door edges recorded when the lift is in use. If a hand is placed between the doors, the reference image could be subtracted from the newly obtained 'operative' image. If an obstruction is present, it will then be visible in the difference image otherwise the difference image should be zero. An example of such a subtractive process is shown in Figures 10d to 10f. The reference images 10b and 10e illustrates a non-obstruction situation and the image 10a and 10d respectively are 'operative' images. The subtracted image 10f and 10c reveals the presence of the hand and its reflection in the edge of the door slamming post.

It is envisaged that a practical implementation of the present invention will involve the use of charge coupled device (CCD) cameras or similar imaging device. The camera systems must be sufficiently fast so that the doors appear stationary for each subsequently collected image. The system will also need to be able to recognise the position of the door obstruction

detection zone and the wider obstruction protection zone from image to image and for various door separations. As the relative position of the doors is known (or can be determined) and the location of features in the image is subject to optics and geometry, it is envisaged that it should be possible to define mathematically the various orientations of the doors and thus how they should appear in each subsequent image. It is also envisaged that during the start-up or initialisation phase of the obstruction detection system, the doorway will be capable of characterisation with the doors fully opened. The detection system will then use this as a starting point and, combined with knowledge of how this image should change with the variable separation of the doors, it should be able to update the various obstruction detection zones as the doors close or open. It is envisaged that such a technique will reduce the computational overhead and thus increase the response time of the system.

Figure 11 illustrates a simplified schematic of an embodiment of the invention. The upper embodiment of Figure 11 shows a single CCD camera 110 positioned to be capable of collecting images of the obstruction detection area from different viewing points. This is effected by mirrors 111, 112, 113 and 114. The horizontal length of the optical arms have been shortened for clarity. Thus the CCD camera 110 can be either comprised of two separate collection devices or a split CCD array. The lower embodiment of Figure 11 illustrates a schematic of a single CCD array parallax detection device. Here, separate images of a scene pass through separate arms of the detector. The selection of the particular viewing point is controlled by electro-optical switches 116 which are controlled by switch 119. A CCD camera collects images 'seen' through alternate optical arms and the parallax detection is made on the basis of switched viewing of the scene. The optical arm is formed using mirrors 116, 117 and 118.

Figure 13 shows a general layout of an embodiment of the present invention in the context of an elevator door. Here a housing 132 is used to locate cameras 131 and 130. Each camera points downward into the obstruction detection area. Figure 14 shows a schematic of the connection between the two cameras, the computer 142 and door controller 143. A triggering signal from the door controller 146 is transmitted to the door hardware which, for example, can operate a relay which opens the doors when the system detects the presence of an obstruction.

In trials, the present invention has been found to be capable of machine-detecting parallax for a reasonably large variety of objects. There are theoretical limits in the parallax which can be detected by the system given the various camera parameters (such as maximum camera separation and height). To this end, it appears that it would be difficult to detect objects that are located less than 200mm above the floor and objects that are placed in the top corners of the lift doorway. However, it is possible that this limit may be overcome by development of camera optics and geometry.

The above-mentioned technique has been developed to allow automatic detection of the sill in door edges. In terms of the requirements of the door edge obstruction detection zone, both techniques – parallax and reference imaging have been found to work well at producing machine identifiable features that corresponded directly to an obstruction being placed in the door obstruction detection zone. The generalised parallax technique has been found to be particularly effective at detecting objects in the wider door detection zone.

Thus the present invention provides for a significantly improved obstruction detection system which can reliably detect a wide range of objects with a height greater than approximately 200mm. Changes in imaging parameters may improve this detection threshold.

The system can further reliably remove the majority of the background from the image to aid in further processing. In addition, it has been found that hands or other obstructions placed at the door edges can be reliably detected - this being done by separating the image into a door edge obstruction detection zone and a wider obstruction detection zone. Numerous variations and modifications will be clear to one skilled in the art. These may include substituting different types of CCD camera or other type of imaging devices. Further, it may be possible to reduce the number of image collection devices to one by means of optical systems such as that described above. This may provide significant cost savings in terms of the requirements of providing two spatially separate viewing points.

Although the present invention has been described in the context of elevator doors, it is possible that, with suitable modification, the invention may be applicable to other obstruction detection applications such as those involved in heavy machinery, process control, safety and the like.

Where in the foregoing description, reference has been made to specific components or integers of the invention having known equivalents, then such equivalents are herein incorporated as if individually set forth.

Although the invention has been described by of example and with reference to possible embodiments thereof, it is to be understood that modifications or improvements may be made thereto without departing from the scope or spirit of the invention.

AS:SO:LAVA:SPEC:801779:001:OBSTRUCTION SENSOR

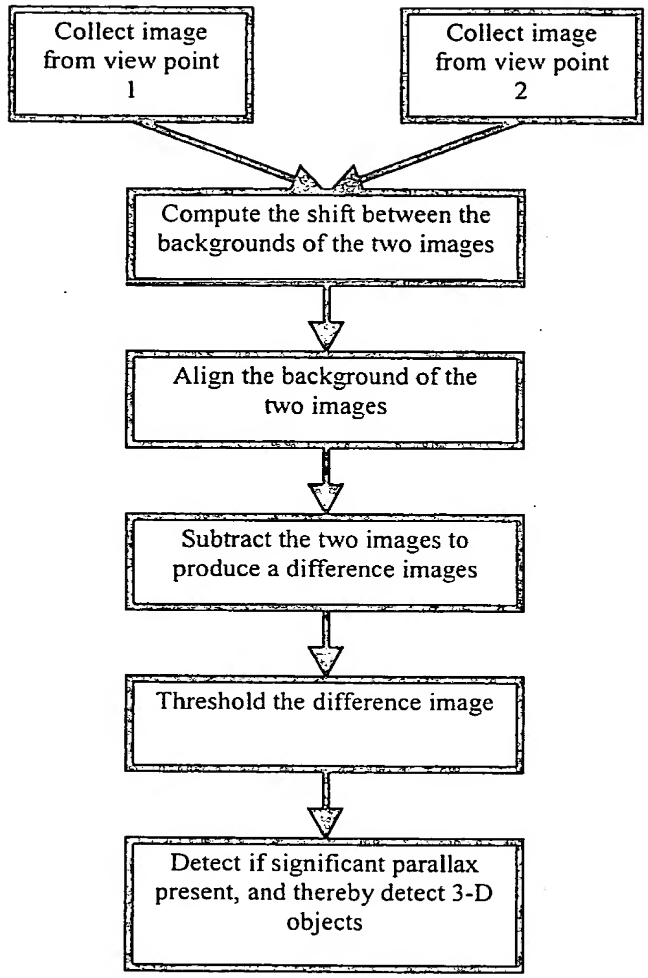


Figure 1

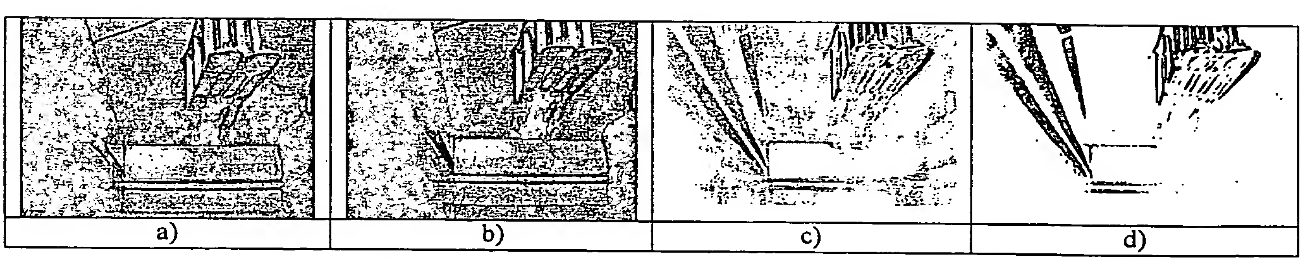
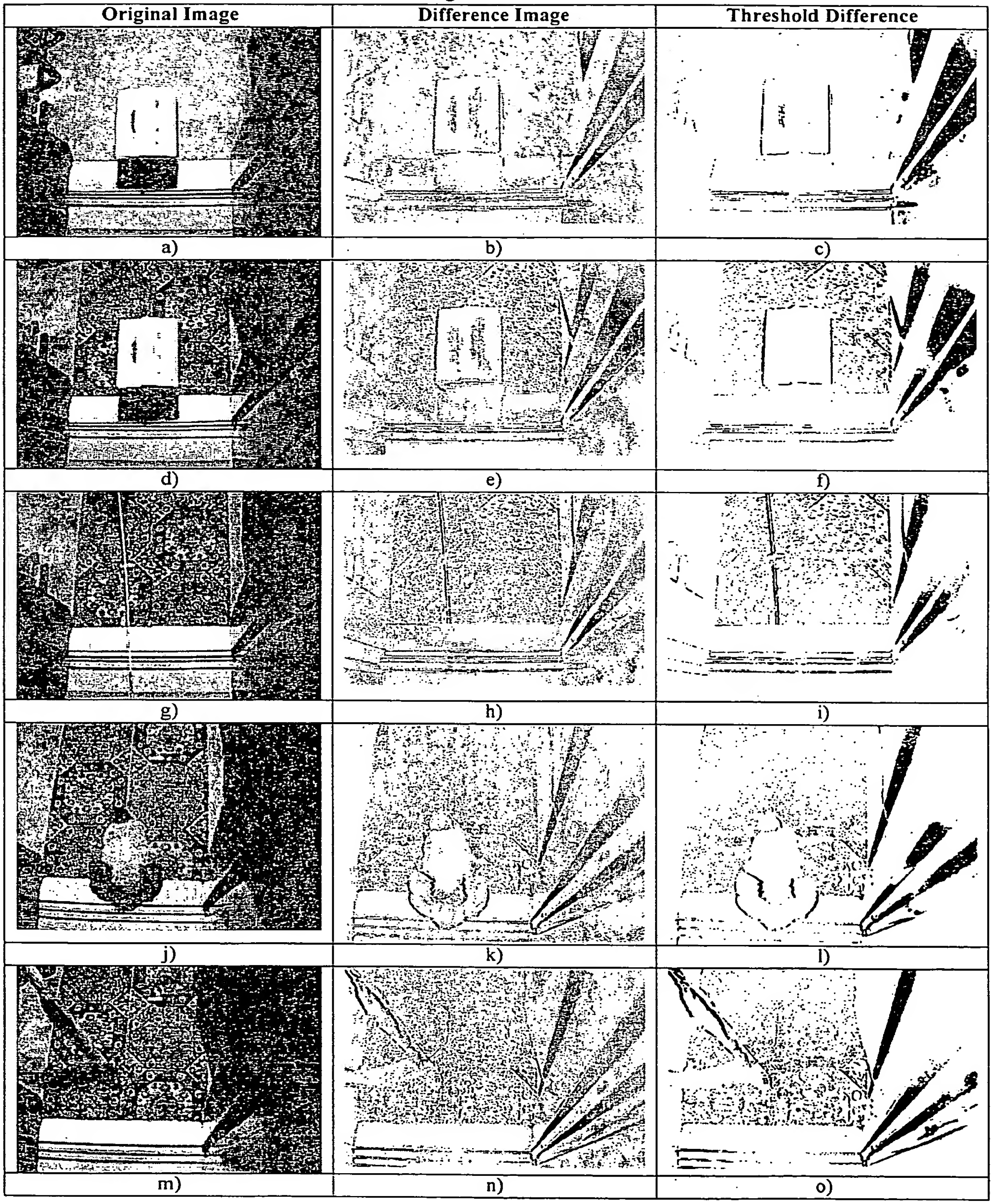


Figure 2

Figure 3



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Difference Image
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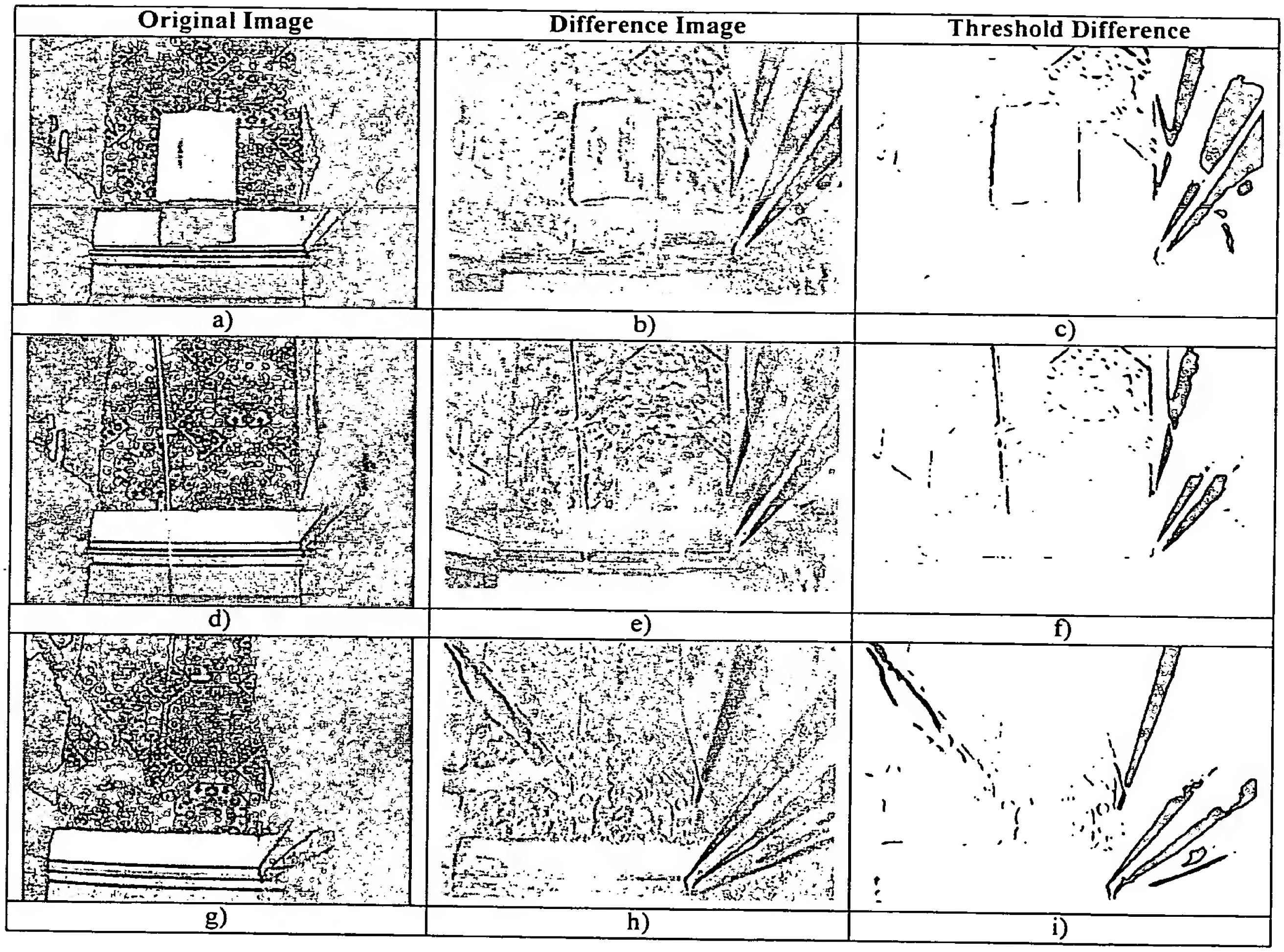
Figure 4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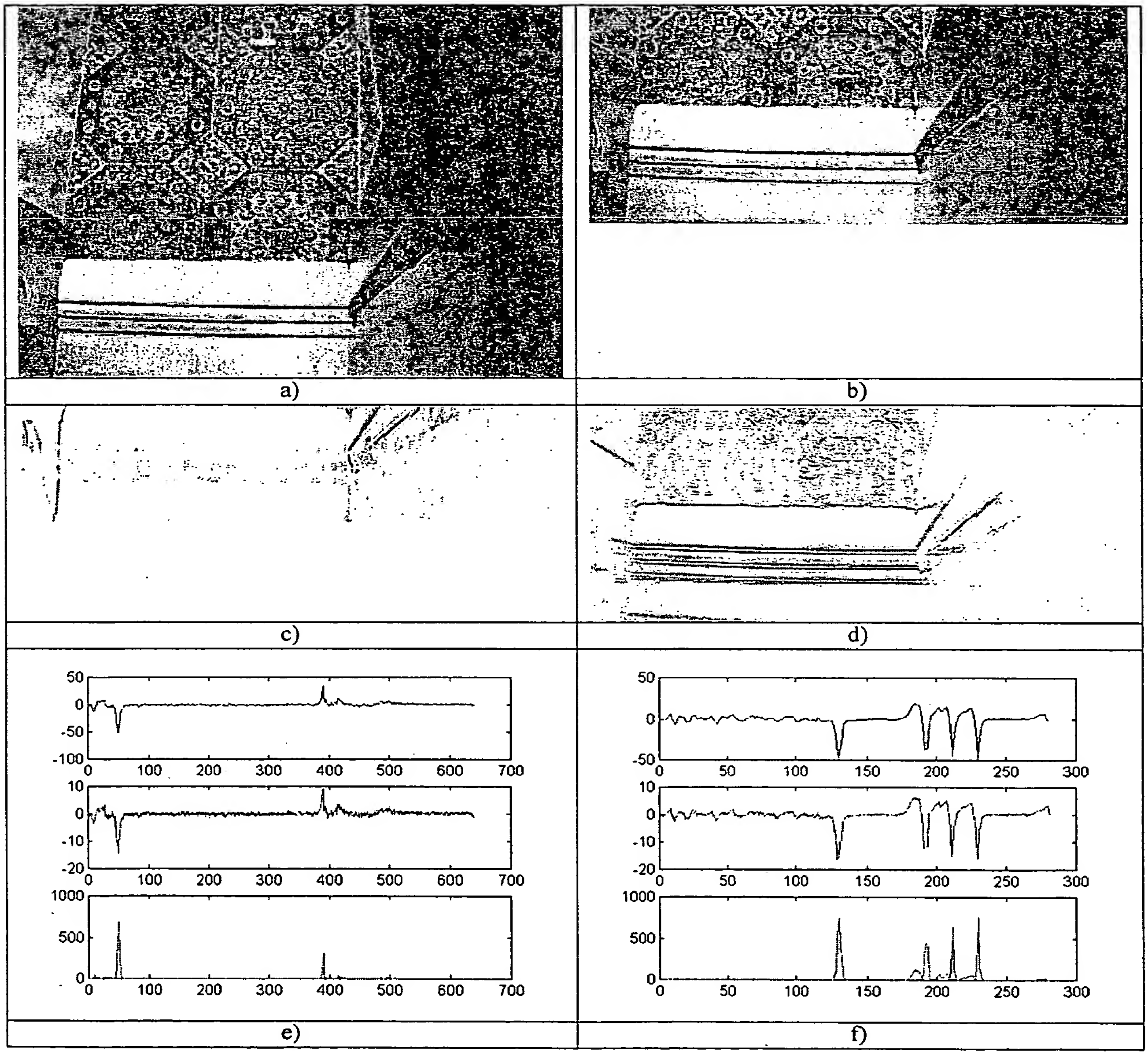
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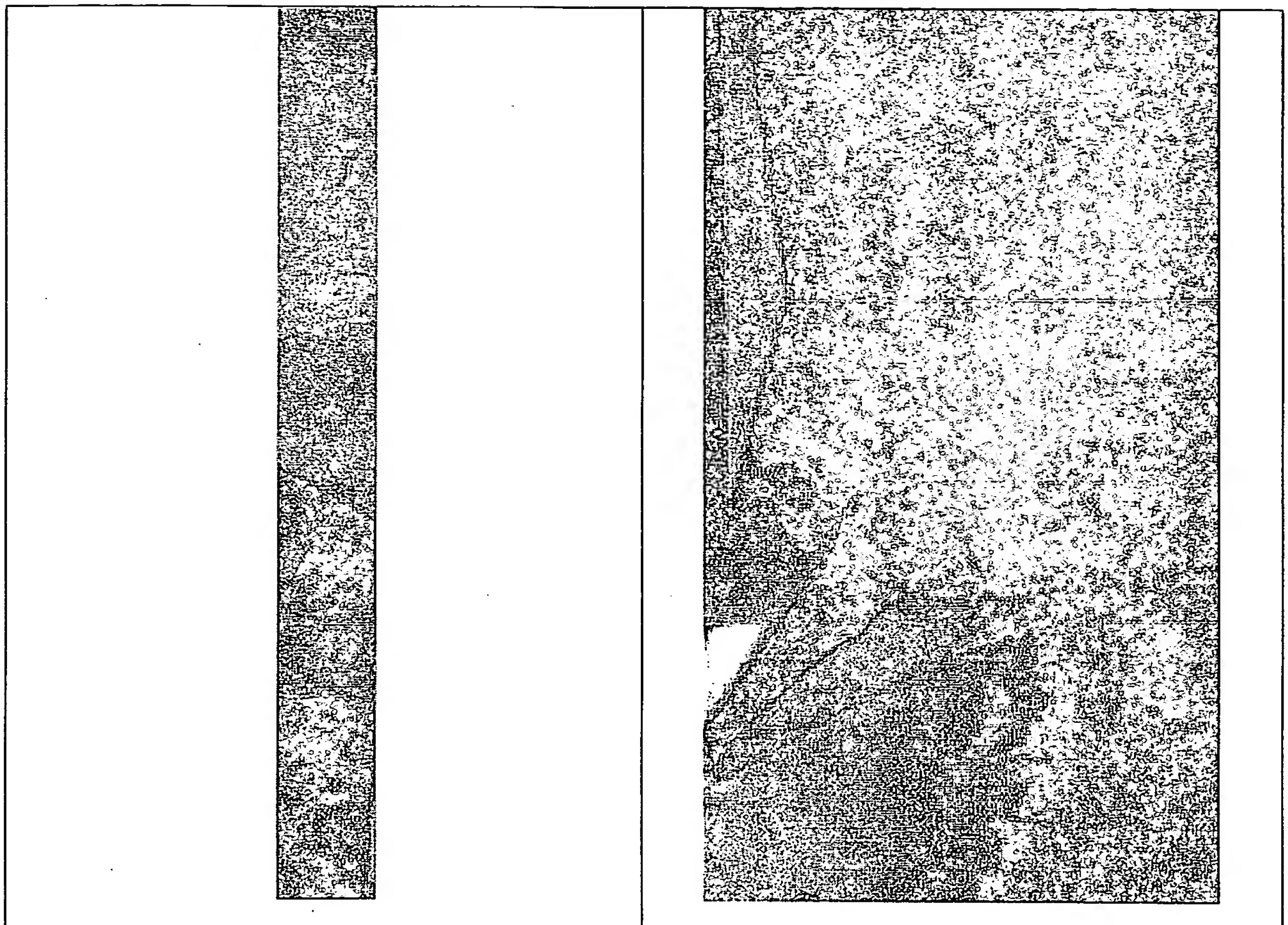
600
700
150
250

Figure 5



a)	b)

Figure 6

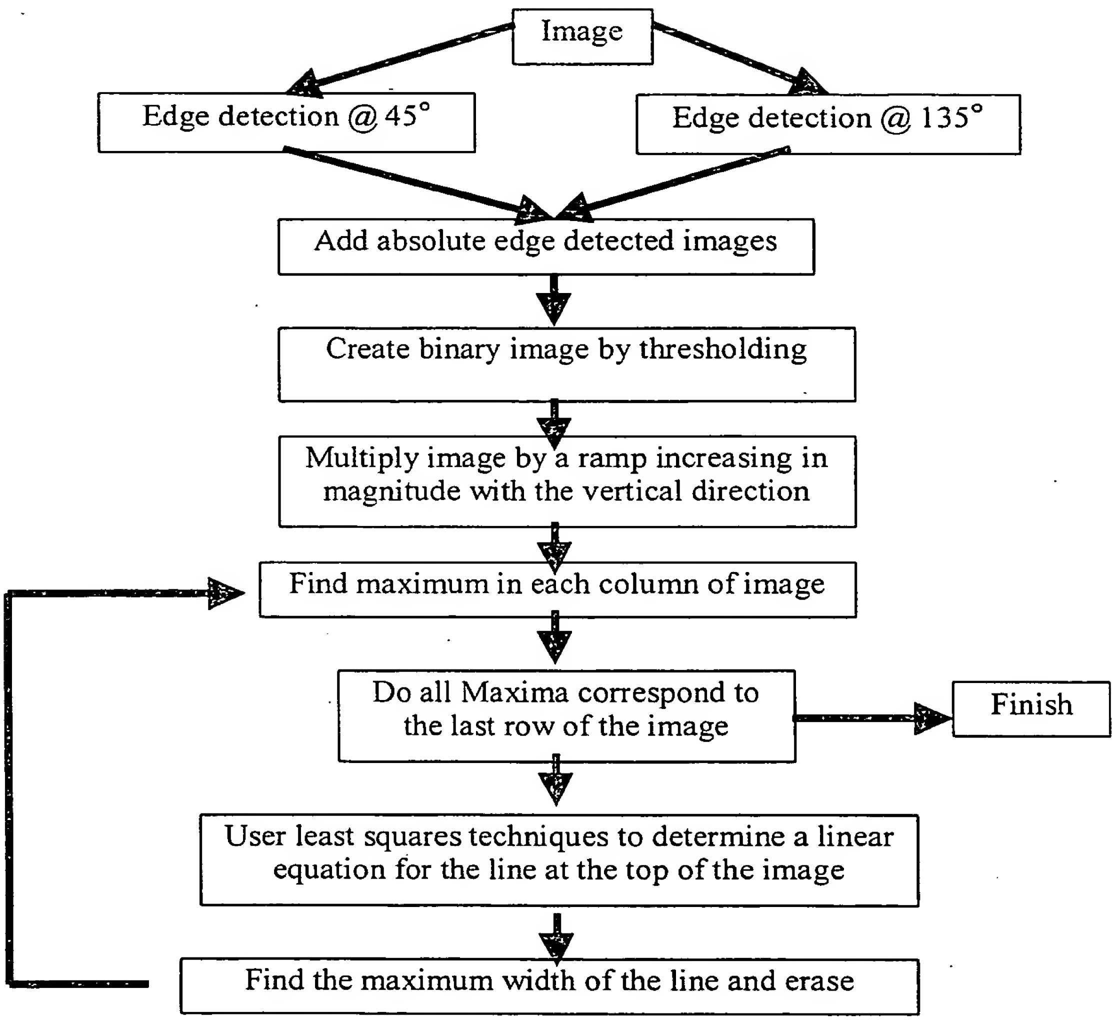
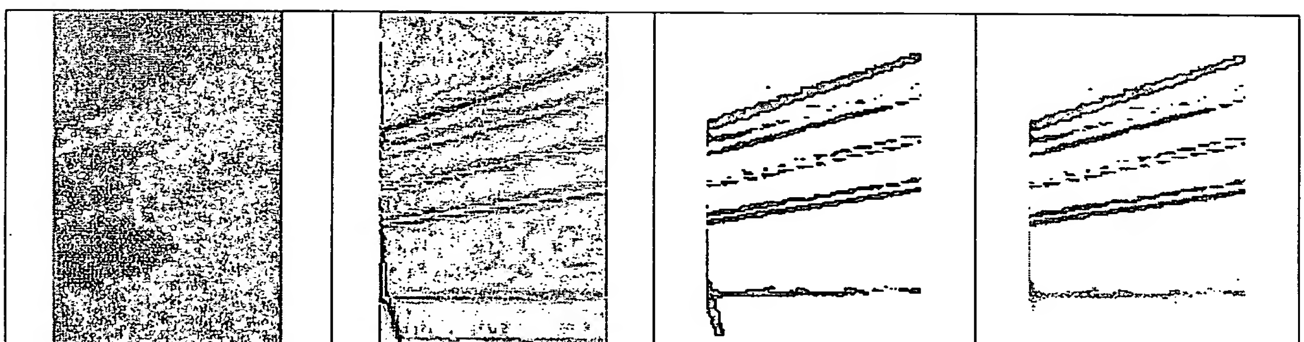


Image
Edge detection @ 45°
Edge detection @ 135°
Add absolute edge detected images
Create binary image by thresholding
Multiply image by a ramp increasing in magnitude with the vertical direction
Find maximum in each column of image
Do all Maxima correspond to the last row of the image
Finish
User least squares techniques to determine a linear equation for the line at the top of the image
Find the maximum width of the line and erase

Figure 7



a) b) c) d)

Figure 8

Figure 9

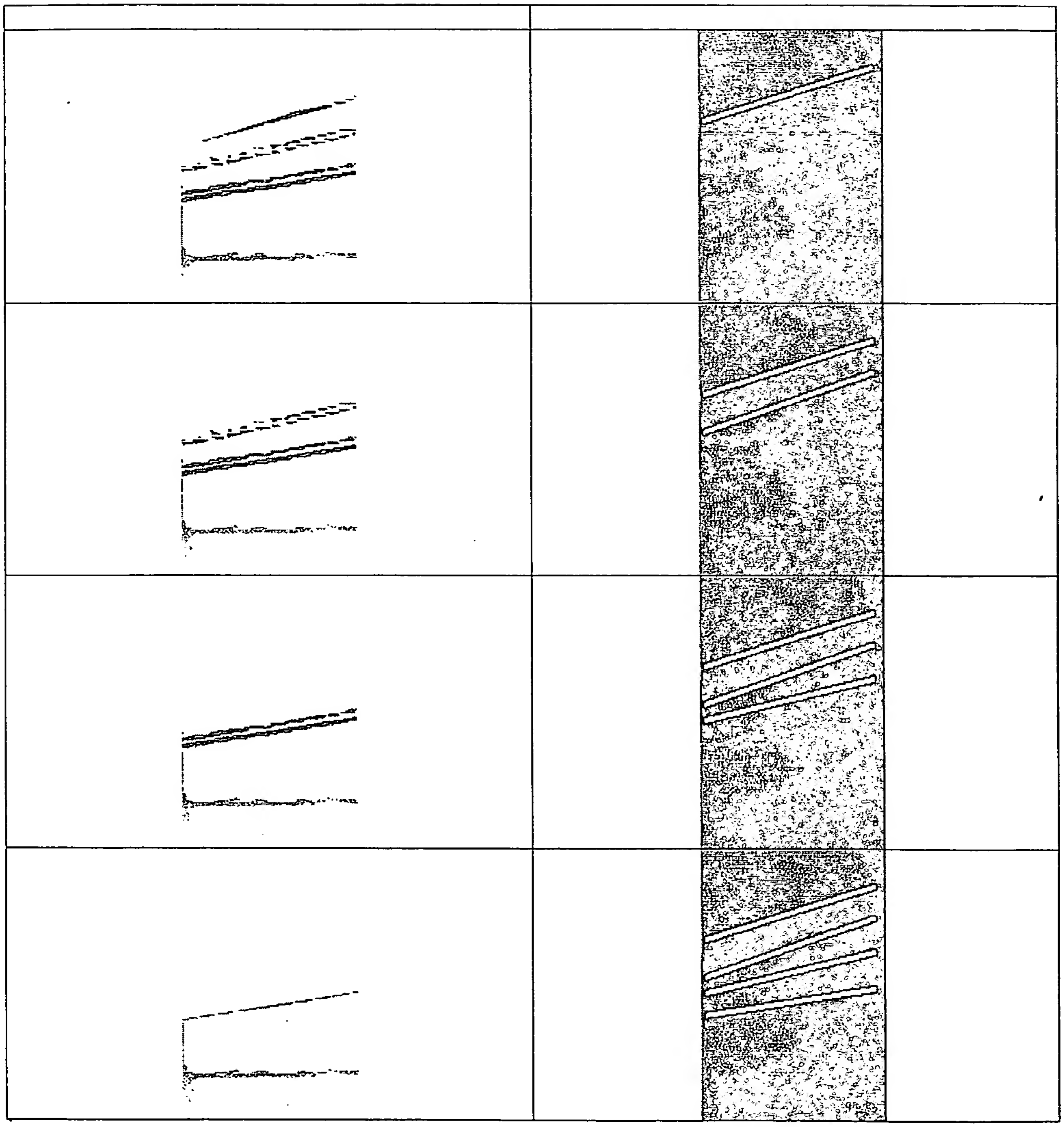


Figure 10a,b,c

With hand	With out hand	Difference
		
a)	b)	c)

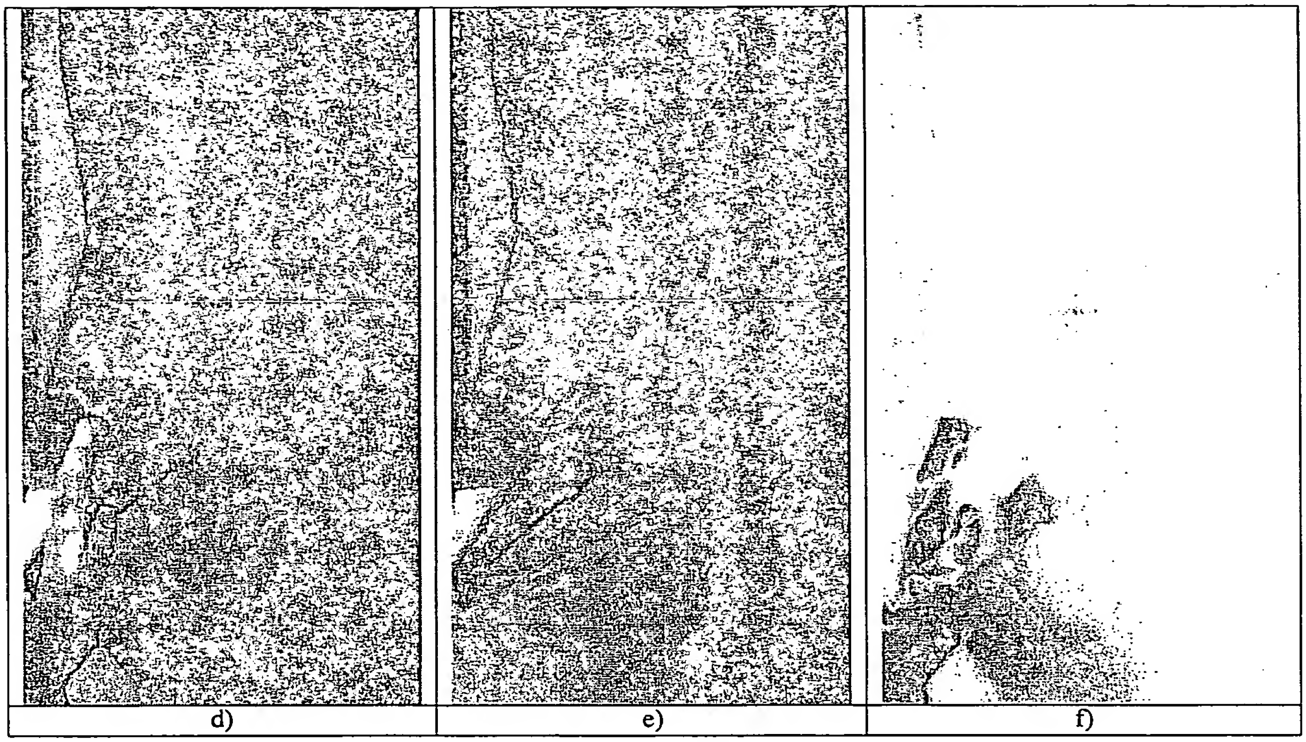


Figure 10d,e,f

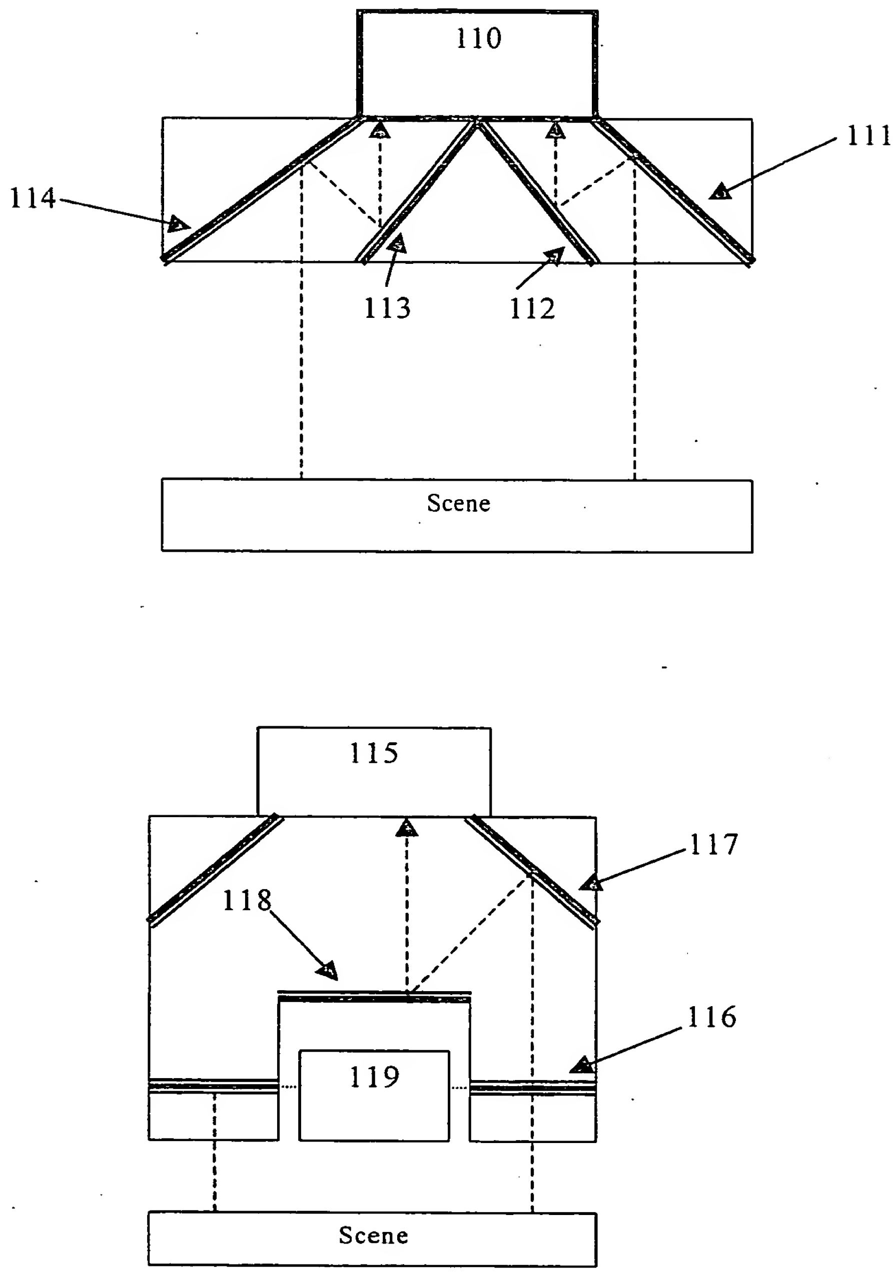


Figure 11

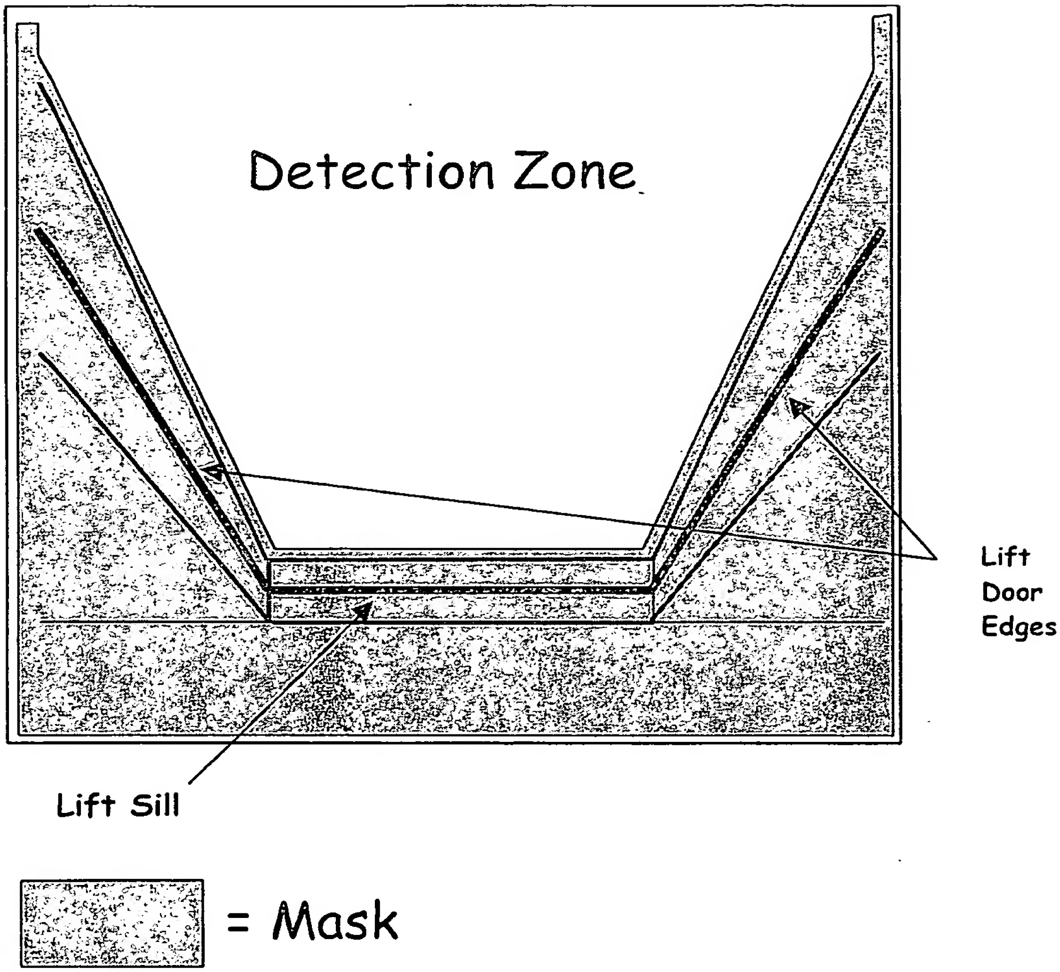


Figure 12

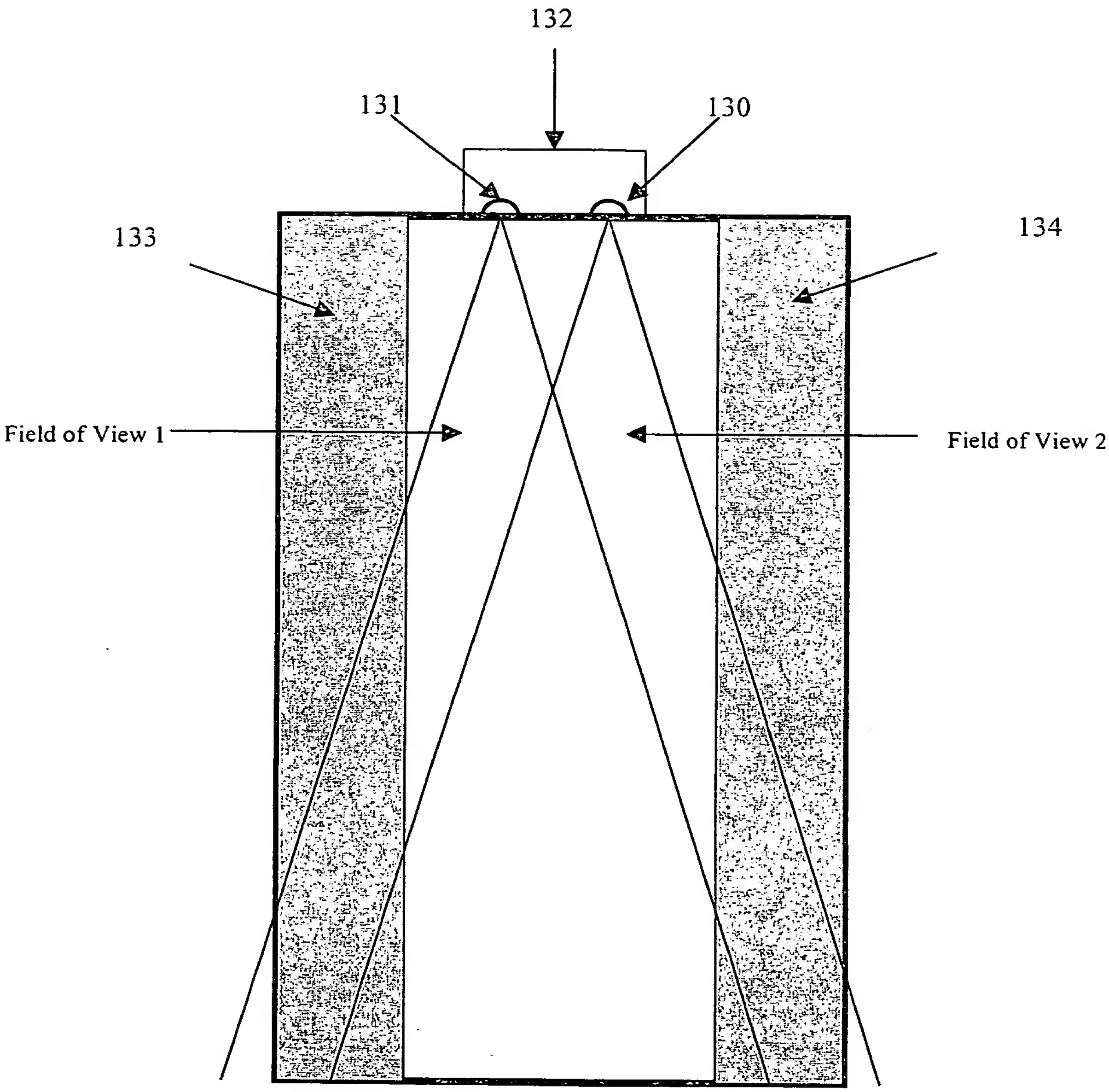


Figure 13

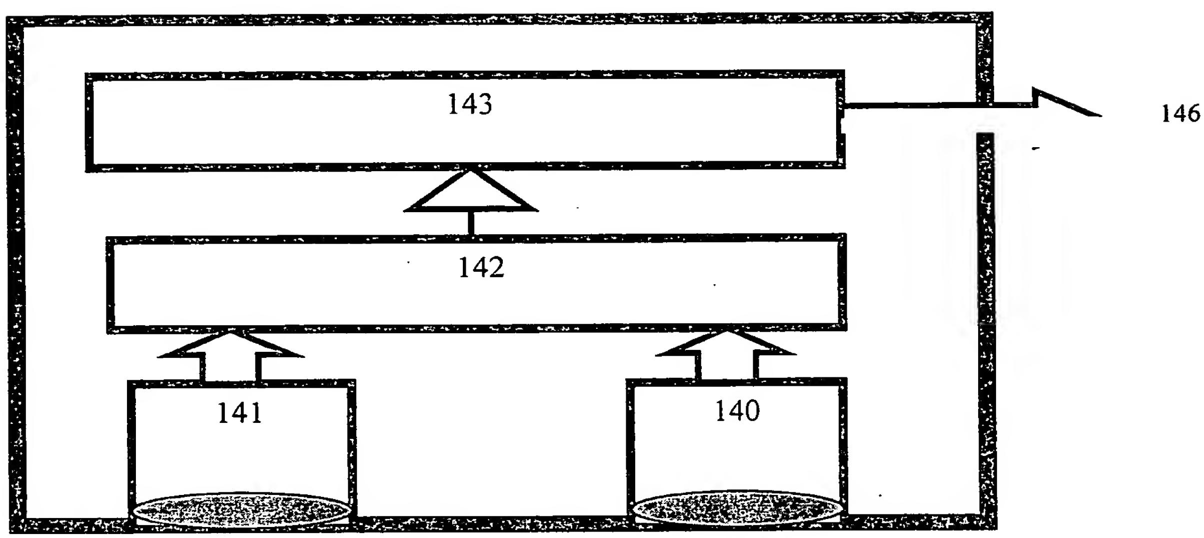


Figure 14